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The degree of damage caused by the sunflower moth (*Homoeosoma nebulellum* [Den. et Schiff.], 1775) to different sunflower varieties

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The degree of damage caused by the sunflower moth (*Homoeosoma nebulellum* [Den. et Schiff.], 1775) to different sunflower varieties

Abstract: The European sunflower moth (*Homoeosoma nebulellum* [Den. et Schiff.], 1775) is one of the earliest documented pests of sunflower. Traditionally considered a two-generation pest, the occurrence of a third generation is becoming more frequent in eastern and central Europe due to global warming. Between 2021 and 2023, we conducted a two-part study in northeastern Hungary: (1) pheromone traps were used at five locations to monitor swarming dynamics, and (2) field trials were carried out to assess larval damage on three sunflower varieties. We compared the susceptibility of the Kisvárdai landrace, the widely grown confectionery hybrid Jaguar, and the oilseed hybrid NK Neoma. Results confirm that the sunflower moth now consistently completes three generations in the region. We found substantial differences in varietal susceptibility: 'Kisvárdai' showed severe damage, while 'Jaguar' and especially 'Neoma' exhibited significantly higher resistance. According to our observations, hot and dry summer conditions–particularly low rainfall from July to September–strongly enhance the intensity of the third generation. Our results also support earlier findings that sunflower varieties with a phytomelanin layer in the pericarp are more resistant to larval damage. However, this feature alone does not provide complete protection.
Key words: sunflower, sunflower moth, swarming dynamics, achene damage

Velikost poškodb, ki jih povzroča sončični molj (*Homoeosoma nebulellum* [Den. et Schiff.], 1775) na različnih sortah sončnic

Izvleček: Evropski sončični molj (*Homoeosoma nebulellum* [Den. et Schiff.], 1775) je eden od prvih registriranih škodljivcev sončnic. Pri škodljivcu, ki ima običajno dve generaciji, se v osrednji Evropi zaradi klimatskih sprememb vedno pogosteje pojavlja tretja generacija. Med letoma 2021 in 2023 sta bili v severovzhodni Madžarski izvedeni dve raziskavi in sicer: (1) za spremljanje dinamike rojenja so bile uporabljene fermonske pasti na petih lokacijah; (2) izveden je bil poljski poskus za oceno poškodb, ki jih povzročajo gosenice na treh sortah sončnic. Primerjane so bile občutljivosti lokalne rase Kisvárdai, zelo razširjenega slaščičarkega hibrida Jaguar in hibrida za olje NK Neoma. Rezultati so pokazali, da ima molj na območju stalno tri generacije. V občutljivosti sort so bile opažene značilne razlike. 'Kisvárdai' je bila močno poškodovana, 'Jaguar', še posebej pa'Neoma' sta pokazali značilno večjo odpornost. Glede na opazovanja vroča in suha poletja, predvsem tista z malo padavin od Julija do septembra, močno pospešujejo velikost pojavljanja tretje generacije. Rezultati raziskave tudi potrjujejo prejšnja spoznanja, da so sorte sončnic s fitomelaninsko plastjo v perikarpu bolj odporne na poškodbe zaradi gosenic a ta lastnost sama po sebi še ne prinaša popolne zaščite.

Ključne besede: sončnica, sončični molj, dinamika rojenja, poškodba rožk

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1 INTRODUCTION

Hungary is the fifth-largest European country for sunflower cultivation, with sunflower farming covering about 15 % of its arable land annually, according to Eurostat (2024).

In the north-eastern part of the country, sunflower growing is important for both the oil-processing industry and food production (Kosztyuné, 2021). For many years, the free-flowering Kisvárdai variety was the most widely grown in this region. The achene shell of this variety does not contain a phytomelan layer, so the sunflower moth (*Homoeosoma nebulellum* [Denis et Schiffermüller], 1775) (Lepidoptera: Pyralidae) can cause significant damage. The role of the phytomelan layer in protecting against the sunflower moth has been the subject of attention in numerous studies (Sárkány, 1947; Seiler et al., 1984; Horváth and Vecseri, 2005).

Szarukán et al. (1996) have observed that both edible and ornamental sunflowers are at risk. Furthermore, they have pointed out the increasing susceptibility of newer sunflower lines, which have diverged from the moth-resistant Russian base material to the pest.

The extent of damage was substantial before the introduction of armored varieties. According to Kadocsa (1947), as many as 30 caterpillars can occasionally be found in a single capitulum, indicating severe infestation. Uzonyi (1942) mentions the damage caused by 30-40 caterpillars on a sunflower inflorescence. In exceptional cases, this number can even reach 300 for sunflowers growing alone. Reichart (1959) records up to 80-90 % seed damage in the Kunhegyes area.

In addition to causing direct damage, pests can also cause indirect damage during rainy weather, which is favorable for pathogens. Pests' chewing provides an entry point for pathogens that cause various plant diseases (Yücel and Tülek, 2020). Uzonyi (1942) noted in the autumn of 1940 that sunflower heads, when damaged, became more susceptible to mold and rot. Horváth and Bujáki (1992) mention the white mold of sunflower (*Sclerotinia sclerotiorum* LIB. DE BARY) as a pathogen that appears after sunflower moth infestation. Kliesiewitz (1979) investigated the relationship between *Rhizopus* infection of sunflower capitulum and *Homoeosoma electellum* (Hulst, 1887) under laboratory conditions. When only infected by *Rhizopus*, the sunflower capitulum showed a 5-20 % rot rate. However, when the sunflower moth also caused damage, the infection rate increased to 55-100 %. Additionally, research revealed that the rot rate of the capitulum rises as the number of harmful larvae increases.

The pest's significance also decreased as the sunflower variety's planting area decreased. In countries with climates different from Hungary, the extent of damage can be substantial. In Romania, Georgescu (2022) drew attention to the fact that pest damage has been rising in recent years, a change linked to climate shifts. Similar problems have been recorded in Turkey, where the spread of sunflower cultivation has gone hand in hand with heavier losses (Yücel and Çobanoğlu, 2016). In Azerbaijan, in addition to assessing the extent of damage, the economic impact of the pest has been analyzed. In the Ganja Ghazakh plant-growing region of Azerbaijan, where the sunflower moth is prevalent, the *Helianthus annuus* 'Giant' variety suffers an annual yield loss of up to 460 kg ha^{-1} (Ismayilzade et al. 2015). China has reported the increasing spread and damage caused by the pest (Cheng et al. 2021). Additionally, Sikora (2017) documented damage to both edible and oil industry varieties by the related species *Homoeosoma electellum*.

In Hungary, the sunflower moth is a two-generation pest. A third wave showed up now and then during the 1950s and 1960s, but has not become regular (Kadocsa, 1947). The first generation lives mostly on wild Asteraceae like *Carduus* and *Cirsium*. Later generations feed on sunflowers, too. As part of the integrated measures to reduce the damage caused by *Homeosoma nebulellum*, an important aspect is the limitation of secondary food sources represented by various plant species. The most effective and reliable methods for reducing these species involve herbicide applications using selective herbicides tailored to specific hybrids or conventional sunflower varieties (Mondici et al., 2023).

From the 1990s onward, stronger late-summer swarming became more common. In 1994 and 1995, Szarukán et al. (1996) reported large third-generation flights in late August and early September. Szabó et al. (2007) later saw an unusually long swarming season in 2005, lasting into mid-October. At the time, these were considered unusual events (Szabó et al., 2008), but now both the second and third generations show up every year and cause damage.

The moth's seasonal timing has shifted. Hot Augusts, fewer early frosts, and dry weather let more larvae survive. These changes seem to support a whole third generation, especially in Hungary and Romania. Other moths have reacted in similar ways to recent climate patterns (Hill et al., 2021; Georgescu et al., 2022).

Many papers blame climate change for these shifts (Sagliker, 2009; Sagliker and Kizildag Özdal, 2021), but we still do not know which weather changes matter the most. It is unclear whether temperature, rainfall, or dry spells are driving the increase in third-generation numbers. This study aimed to:

- monitor the seasonal flight activity of the sunflower moth across multiple locations,
- assess the extent of infestation and seed damage in different sunflower hybrids, and
- explore the relationship between pest dynamics and seasonal weather conditions.

2 MATERIALS AND METHODS

The study consisted of two distinct but related experimental components: (1) moth flight monitoring using pheromone traps at multiple locations, and (2) field assessment of larval damage on sunflower capitula under controlled varietal conditions.

2.1 PHEROMONE TRAP MONITORING

Moth activity was monitored at five different commercial sunflower-growing sites in Eastern Hungary: Oros, Felsősima, Nagycserkesz, Nyírtelek, and Kálmánháza. In this region, the plant is typically grown on acidic, nutrient-poor, sandy soils with poor water management due to its modest soil requirements. Such lands were used as the basis for our research in all three years. At each site, two pheromone traps were installed (n = 10 traps total per year), positioned at approximately 50–500 meters from each other, depending on field layout. All sites cultivated sunflowers for human consumption, under typical regional agronomic practices. CSALOMON sticky sunflower moth traps made of transparent plastic with a triangular cross-section (MTA Plant Protection Research Institute, Budapest) were used to monitor the swarming pattern. The components of the lure are Z11-16Al, Z13-18Al, and Z9E12-14Al 150:120:15 (Szarukán et al., 1996).

The traps operated from the second week of April until the middle of September. The number of male insects caught in the traps was checked and noted weekly. The pheromone capsules were replaced every five weeks, and the adhesive sheets were changed as required. Trap data from each date (n = 10, 2 traps per site × 5 locations) were used to calculate the standard deviation to evaluate the variation in moth captures across different sampling dates. Higher standard deviation values indicate a more uneven distribution among traps, suggesting that swarming was less uniform.

2.2 FIELD EXPERIMENT FOR DAMAGE ASSESSMENT

The field trial to assess pest damage was carried out at the experimental farm of the University of Nyíregyháza, located in Nyírtelek–Ferenc Tanya (GPS: 48.009958, 21.57629). The exact sunflower plot changed each year due to crop rotation. Across all three years (2021–2023), the experiment was conducted on a single plot per year, ranging in size from 6,000 to 10,000 m², depending on the available field area. The three sunflower varieties were planted in adjacent strips of equal area, each occupying one-third of the given plot. The same agronomic practices were applied throughout to minimize differences in microclimate or soil conditions.

Two weeks after the peak of the second-generation flight, 100 sunflower heads were collected per variety. The infestation rate and seed damage were recorded for each capitulum. Sunflower heads were selected through simple random sampling within each variety's plot. We focused on the damage observed following the 2nd generation's emergence.

In our study, we tested the infestation of three different sunflower varieties:

1. Kisvárdai: a long-growing season, free-flowering variety lacking a phytomelane layer, prone to branching and forming branch inflorescence.
2. Jaguar: the most common confection hybrid.
3. NK Neoma: a widely cultivated hybrid for the oil industry.

2.3 WEATHER CONDITIONS

Meteorological data were collected from the automated weather station located at the University of Nyíregyháza's experimental farm in Nyírtelek–Ferenc-farm (GPS: 48.009958, 21.576290). Daily air temperatures and total precipitation were compiled into monthly values for 2021-2023, focusing on April to September (vegetation period). To assess recent deviations, long-term climate averages from 1870 to 2002 from the Hungarian Meteorological Service (OMSZ) were used as a reference, representing national norms (Table 1).

The summer of 2023 was arid. In July, August, and September, precipitation reached only 1.2 %, 7.7 %, and 14.9 % of the historical averages, respectively. Average temperatures in these months were also higher than the long-term means by 8.3 %, 14.6 %, and 23.2 %, respectively. This combination of heat and drought may have influenced moth development and host plant vulnerability.

Table 1: Monthly average temperature (°C) and total precipitation (mm) for the study years 2021–2023, compared to long-term historical averages (1870–2002).

Months	Precipitation (mm)			
	2021	2022	2023	Average (1870-2002)
January	61.9	10.0	96.2	29.5
February	59.2	11.7	16.8	30.0
March	18.7	21.9	71.8	30.0
April	59.7	42.1	72.6	39.5
May	90.6	3.9	67.0	54.0
June	14.9	21.9	45.2	76.0
July	45.4	35.4	0.8	66.5
August	59.3	20.3	5.0	65.0
September	21.5	149.6	6.4	43.0
October	1.7	15.4	30.8	44.0
November	65.4	47.6	76.0	46.5
December	47.5	142.4	113.6	40.5
Total	545.8	522.2	602.2	564.5
Months	Average temperature (°C)			
	2021	2022	2023	Average (1870-2002)
January	1.2	-0.2	4.2	-2.4
February	1.5	3.7	2.7	-0.1
March	4.9	4.8	6.9	4.6
April	9.0	9.2	9.5	10.7
May	14.9	17.4	16.2	15.9
June	22.1	22.2	19.4	19.0
July	24.1	23.4	22.3	20.6
August	20.2	23.4	22.7	19.8
September	15.7	15.4	19.1	15.5
October	9.1	11.8	13.4	9.9
November	4.6	5.8	5.6	4.2
December	1.1	2.2	2.5	-0.4
Average	10.7	11.6	12.0	9.8

Weather data for 2021–2023 were recorded at the automated meteorological station of the University of Nyíregyháza, Nyírtelek–Ferencfarm. Historical climate averages were obtained from the Hungarian Meteorological Service (OMSZ).

2.4 STATISTICAL ANALYSIS

2.4.1 Pheromone Trap Data

To evaluate the daily consistency of moth captures, we calculated the standard deviation of trap counts for each sampling date. At every time point, data from 10 traps were collected across the five monitored locations (two traps per site). The standard deviation reflects the variation in captures across these 10 traps on a given day and provides insight into the uniformity of moth swarming intensity on that specific date.

2.4.2 Damage Data

To analyze the effect of sunflower variety on moth-related damage, we used a one-way analysis of variance (ANOVA). The independent variable was the sunflower hybrid, and the dependent variables were (1) the number of damaged capitula and (2) the number of damaged seeds per head. Data was collected from three varieties over three years, with 100 samples taken from each hybrid annually.

The assumptions for ANOVA were verified:

- The dependent variables were metric, and the independent variable was nominal.
- Sample sizes were equal, with random sampling from each variety.
- Observations were independent, ensured by experimental design.
- Normality and equal variances were confirmed using a goodness-of-fit test and Levene's test, respectively (Hódiné, 2018).

To assess the relationship between variety and damage, we used two indicators: the standard deviation ratio (H) and the coefficient of determination (H^2). The standard deviation ratio shows relative variability, and the coefficient of determination indicates the variance explained by variety differences (Hunyadi et al., 2001; Makszim, 2019; Obádovics, 2009).

3 RESULTS AND DISCUSSION

3.1 PHEROMONE TRAP MONITORING

We followed the sunflower moth's swarming from 2021 to 2023 using pheromone traps set at five different sites. In 2021 and 2022, the first generation stayed weak. In 2023, however, swarming started a bit earlier: the first notable catches were already seen at the end of May. The second generation remained low in all three years. The third generation appeared each year, but in 2023, its intensity was higher than before (Figure 1).

This fits earlier findings by Szabó et al. (2007), who described stronger third-generation after hot and dry summers. A similar trend was also noted in Romania (Georgescu et al., 2022). However, those studies did not

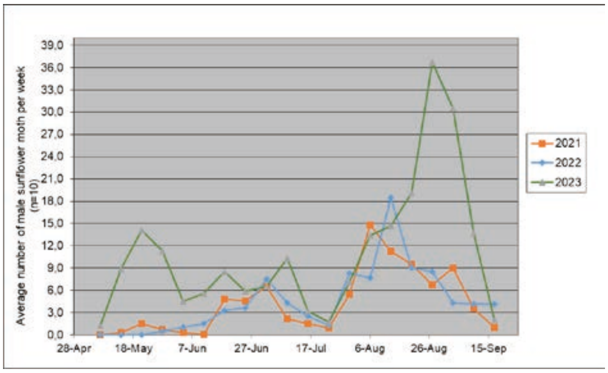

Figure 1: Seasonal flight pattern of the sunflower moth in 2021, 2022, and 2023.

include monthly climate data, so it's still unclear which specific weather factors, like rainfall in certain months, drive the increase.

Our data show that the third generation peaked in the week of September 3 (week 36), with an average of 36.7 moths per trap. This happened after an arid summer: July and August together brought only 5.8 mm of rain, just 4.4 % of the usual average of 131.5 mm. September was dry too, with 6.4 mm instead of the normal 43 mm (15 %) (Table 1).

This long dry spell likely helped not just the development of the third generation, but its survival, too. With no rain, eggs and larvae were not washed off the leaves, so more of them could survive.

To track how moth numbers changed over time, we calculated the standard deviation for each sampling date (10 traps per week). These values–averages, standard deviations, and relative standard deviations (RSD %)–are shown in Table 2.

We saw that when moth numbers were low, the relative standard deviation between traps tended to be high. That is expected: when the average is near zero, even one or two moths in a trap can throw off the numbers. But when swarming was strong, the RSD dropped below 30 %, showing that the data were more consistent and reliable.

Table 2: Average catch of sunflower moths, standard deviation and relative standard deviation (2021-2023) (n = 10).

Years	2021			2022			2023		
Week	Average catch of sunflower moths	Standard deviation	Relative standard deviation	Average catch of sunflower moths	Standard deviation	Relative standard deviation	Average catch of sunflower moths	Standard deviation	Relative standard deviation
07.05.	0	0.00	-	0	0.00	-	0	0.00	-
14.05.	0.3	0.67	225 %	0	0.00	-	1.2	1.03	86 %
21.05.	1.5	1.27	85 %	0	0.00	-	8.9	3.87	44 %
28.05.	0.7	0.67	96 %	0.5	0.53	105 %	14.1	3.75	27 %
04.06	0.3	0.67	225 %	1	0.67	67 %	11.3	3.37	30 %
11.06.	0.1	0.32	316 %	1.5	1.43	96 %	4.5	2.80	62 %
18.06.	4.8	3.52	73 %	3.3	2.41	73 %	5.6	2.59	46 %
25.06.	4.6	2.22	48 %	3.7	2.63	71 %	8.5	1.84	22 %
02.07.	6.5	3.10	48 %	7.5	2.22	30 %	5.9	2.77	47 %
09.07.	2.2	1.81	82 %	4.3	2.41	56 %	6.5	2.46	38 %
16.07.	1.5	1.27	85 %	2.5	1.08	43 %	10.3	2.58	25 %
23.07.	1	0.94	94 %	1.3	0.82	63 %	3.2	2.25	70 %
30.07.	5.4	3.44	64 %	8.3	1.42	17 %	1.7	1.64	96 %
06.08.	14.8	4.05	27 %	7.7	1.77	23%	7.1	2.69	38 %
13.08.	11.2	2.82	25 %	18.6	2.63	14 %	13.4	3.63	27 %
20.08.	9.5	2.88	30 %	9	2.40	27 %	14.7	3.59	24 %
27.08	6.7	2.67	40 %	8.5	2.22	26 %	19.1	3.00	16 %
03.09.	9	2.40	27 %	4.3	1.89	44 %	36.7	5.44	15 %
10.09.	3.5	2.01	58 %	4.1	2.18	53 %	30.5	4.12	13 %
17.09.	1	0.94	94 %	4.1	1.91	47 %	13.7	3.40	25 %

On May 29, June 26, and during the last four sampling dates (August 20–September 17), trap counts were higher and more even, with RSD values under 30 %. These dates were considered statistically homogeneous. On other dates, the RSD was above 30 %, usually because the total moth count was low (Table 2).

3.2 FIELD EXPERIMENT FOR DAMAGE ASSESSMENT

The infestation patterns were similar across the three years of the study. As expected, the Kisvárdai landrace, without a protective phytomelanin layer, was the most severely affected. In 2023, more than half of the sampled sunflower heads from this variety showed signs of larval damage. The Jaguar hybrid also showed susceptibility in two of the three years (2021 and 2023), with over 10 % of heads affected. In contrast, the Neoma hybrid showed markedly better resistance: only 11 damaged capitula were found in 2021 and a single case in 2023. The lowest infestation levels across all three varieties were observed in 2022 (Table 3).

Interestingly, while the Kisvárdai variety showed the highest infestation in 2023, consistent with the intense third-generation swarming, that year was not the most damaging for Jaguar and Neoma. In both of these hybrids, higher levels of damage were observed in 2021. This difference may come from several factors, such as when flowers bloom, local climate conditions, or the availability of nearby host plants. We need to investigate further to fully understand these patterns.

Across the three years of observation, there was a statistically significant difference in capitulum damage between the sunflower varieties ($p < 0.001$). The Neoma hybrid consistently showed the lowest levels of head damage, indicating strong resistance to larval attack. At the other extreme, the Kisvárdai landrace proved to be the most vulnerable. Therefore, we can classify 'Neoma' as the most resistant, 'Jaguar' as moderately susceptible, and 'Kisvárdai' as the most vulnerable variety.

Table 3: Mean number of sunflower heads damaged by *Homoeosoma nebulellum* Den. et Schiff. per 100 plants (mean ± standard deviation) for each variety and year of study.

	Number of infested capitulum/100 plants		
Years	2021	2022	2023
Neoma average	11	0	1
Neoma standard deviation	0.24	0.00	0.10
Jaguár average	18	2	11
Jaguár standard deviation	0.40	0.14	0.31
Kisvárdai average	20	18	52
Kisvárdai standard deviation	0.46	0.39	0.50

Table 4: Mean number of sunflower seeds damaged by *Homoeosoma nebulellum* Den. et Schiff. per head (mean ± standard deviation) for each variety and year of study.

	Number of damaged seeds/100 plants		
Years	2021	2022	2023
Neoma average	0	0	0
Neoma standard deviation	0.00	0.00	0.00
Jaguár average	70	6	54
Jaguár standard deviation	0.91	0.45	1.57
Kisvárdai average	166	98	217
Kisvárdai standard deviation	2.17	2.21	2.27

The analysis of variance indicated that the variety accounted for 35 % of the variation in head damage in 2021, 10 % in 2022, and only 1 % in 2023. This suggests that genotype had a greater influence during years of moderate infestation levels.

Seed damage analysis showed no sign of larvae penetrating the seeds of the Neoma variety in any of the three years. By contrast, the Jaguar variety displayed some level of seed injury in every season. Even in 2023, the year with the highest infestation, capitula of the Kisvárdai variety contained, on average, just over four chewed seeds per head (Table 4).

In 2021, there was a statistically significant link between the sunflower variety and the number of seeds damaged by the sunflower moth ($p < 0.001$, H = 0.67). The relationship was still significant in 2022 ($p < 0.001$) but weaker (H = 0.33). In 2023, we again found a significant, moderately strong association ($p < 0.001$, H = 0.50).

Based on the coefficient of determination, the sunflower variety explained 45 % of the variation in seed

Table 5: Results of one-way ANOVA comparing capitulum and seed damage across sunflower varieties (df = 2, 297; F-critical = 3.03; all results significant at $p < 0.001$).

	Infested capitula/100 plants	Damaged seeds/100 plants	
Years	F-calculated	F-calculated	p-value
2021	78.85	119.42	< 0.001
2022	17.29	17.87	< 0.001
2023	60.69	50.47	< 0.001

damage in 2021, 11 % in 2022, and 25 % in 2023. ANOVA results showed that the differences in damage levels were explained entirely by the variety. Variation between the groups, based on the standard deviation of their means, was consistently greater than the variation within the groups, measured as the average of the standard deviations inside each group. F-tests confirmed this pattern, with calculated F values exceeding the critical thresholds in every case, indicating that variety had a statistically significant effect on both capitulum and seed damage (Table 5).

4 CONCLUSIONS

In all three years, we observed a complete third generation of *Homoeosoma nebulellum*, which goes beyond earlier reports that mostly mentioned only partial third-generation activity (Kadocsa, 1947). Our findings support previous observations by Szabó and Georgescu, who pointed to weather as a key factor in shaping pest populations.

Based on our data, we were able to narrow this effect down: it was the dry and hot conditions in July, August, and September, especially the lack of rainfall, what likely created ideal conditions for the third generation to build up in large numbers.

As for damage levels, the three tested sunflower varieties responded differently. 'Neoma' proved to be the least affected, 'Jaguar' showed moderate sensitivity, while 'Kisvárdai' was the most vulnerable.

Although the swarming intensity seems strongly linked to temperature and precipitation, the actual damage to sunflower heads did not follow the same trend. Since we found no consistent link between temperature and the level of damage, we assume that flowering time and possibly the presence of other host plants nearby may have a greater influence on how much damage occurs each year.

These insights can inform breeding programs and pest management strategies to mitigate damage under future climate scenarios.

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